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Habitat Use by Spikedace, Meda fulgida (Pisces: Cyprinidae) in Southwestern Streams with Reference to Probable Habitat Competition by Red Shiner, Notropis lutrensis (Pisces: Cyprinidae)

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HABITAT USE BY SPIKEDACE, *MEDA FULGIDA* (PISCES: CYPRINIDAE) IN SOUTHWESTERN STREAMS WITH REFERENCE TO PROBABLE HABITAT COMPETITION BY RED SHINER, *NOTROPIS LUTRENSIS* (PISCES: CYPRINIDAE)

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ABSTRACT—Spikedace, *Meda fulgida,* used habitat in several southwestern desert streams in proportion to availability of habitat types. Velocity of water occupied by spikedace did not increase with increased stream size. Schools of >10 spikedace frequented deeper (mean 27 cm) and slower-moving (<25 cm/s) waters characterized by eddying currents and shear zones often associated with stream gradient adjustments. Comparison of habitat used by spikedace both with that described in the literature and that measured in one southwestern stream for the introduced red shiner, *Notropis lutrensis,* suggests habitat partitioning may occur when these two cyprinids co-occur in a stream.

The spikedace, *Meda fulgida,* is a monotypic genus endemic to the Gila River basin, Arizona and New Mexico (Miller and Hubbs, 1960; Minckley, 1973). Although spikedace can be spatially and temporally abundant, its range has been markedly reduced within the basin. It is a small (<100 mm total length) cyprinid that is currently listed as a threatened species by both state (Arizona Game and Fish Commission, 1982) and federal (United States Department of the Interior, 1986) agencies. In addition, the state of New Mexico lists the species as endangered (J. P. Hubbard et al., in litt.).

Most literature on the species addresses its distribution and taxonomy (Miller and Hubbs, 1960; Minckley, 1969; LaBounty and Minckley, 1972; Minckley, 1973). Information on life history of spikedace has come largely from studies in Aravaipa Creek, southeastern Arizona (Barber et al., 1970; Schreiber and Minckley, 1981). The most recent information is from the upper Gila River in New Mexico (D. L. Propst et al., in litt.). Rinne and Kroeger (1988) have described physical habitat use (with respect to velocity and depth of water and substrate) by spikedace in Aravaipa Creek.

Because of the status of the spikedace and the presence in the published literature of only general comments on its habitat requirements (Miller and Hubbs, 1960; Minckley, 1973), this study was initiated to quantify the habitat requirements of spikedace in several southwestern desert streams. Habitat data were obtained in several streams in the upper Gila River basin, New Mexico, and in the Verde River, Arizona, in addition to Aravaipa Creek (Rinne and Kroeger, 1988). A non-native cyprinid, the red shiner (*Notropis lutrensis*), introduced into Arizona in 1953 has been implicated as a potential competitor. The two cyprinids have been taken together frequently by me and others in the same seine haul or electrofishing pass in the upper Verde and to some extent in the upper Gila basin streams (D. L. Propst, pers. comm.). Cursory description of spawning habitat for the two species in the Southwest indicates that the two species are very similar (Barber et al., 1970; Minckley, 1972). Habitat use by red shiner as reported in the literature and as measured in one stream in Arizona is discussed relative to habitat use by spikedace.

MATERIALS AND METHODS—Aravaipa Creek was a low-gradient (<1%), small (3 to 5 m wide), often braided, hydrologically stable stream with primarily gravel-pebble (3 to 64 mm) substrate. Modal discharge ranged between 0.5 and 1.0 m^3/s, with greatest flow in winter months. However, late summer storms were capable of producing sudden, sometimes violent floods. For a detailed description of Aravaipa Creek, see Barber and Minckley (1966) and Rinne (1989). The Verde River

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and streams in the upper Gila River basin (lower Gila River at Cliff, and Middle and West Forks of Gila River) were generally higher gradient (2 to 5%), larger in size (5 to 30 m wide) and at higher elevation (>1,200 m) than was Aravaipa Creek. Similar to Aravaipa Creek, the streams in the upper Gila River were subject to highly variable discharges (D. L. Propst et al., in litt.) but modal flows were greater.

Sample sites were selected based upon my previous experiences with collection of spikedace and upon qualitative description of its habitat (Barber and Minckley, 1966; Minckley, 1973). Aravaipa Creek was sampled seven times during the period 1982 to 1985 to include winter (December through February), spring (April through May), and summer (August through September) seasons (Rinne and Kroeger, 1988). Sampling in the upper Gila basin, New Mexico, was conducted only in spring (June) 1983 at six sites: two sites in the Gila River near Cliff, New Mexico (lower Gila River site), one site each in the Middle and West forks of the Gila River, one each in the San Francisco River and Tulerosa Creek (see Rinne, 1989); spikedace were taken only at the three sites (Table 1). Sampling in the Verde River was in April 1985, December 1988, and January 1990. Data from winter and spring (December 1982, February 1984, April 1983, 1984, and May 1985) sample dates in Aravaipa Creek were combined and compared with data from the upper Gila and Verde rivers. Because habitat data collected in April 1985 and December 1988 in the Verde River were not significantly different ($P < 0.05$), data from this site were combined. Habitat transects in reaches of streams sampled were chosen by location of initial capture of spikedace. At least two more transects were sampled: one 5 m upstream and one 5 m downstream. If spikedace were captured at either of these transects, then additional transects were established in an upstream or downstream direction (Rinne, 1985). A maximum of nine transects was sampled in addition to the initial transect where spikedace were found. If spikedace were absent, sampling effort was moved to another reach of stream at the sampling site. Further, if spikedace were rare at a site, transects were established wherever they could be collected rather than at 5-m intervals.

Spikedace were immobilized by electrofishing and captured by a 1-meter block net positioned about 1 to 2 m downstream (Rinne, 1985). Physical habitat characteristics of these approximately 1- to 2-m^2 sample areas (not all with spikedace) were measured using a meter transect method and a habitat sampler (Rinne, 1985, 1989). With this apparatus, one set (velocity, depth, substrate) of 21 measurements each (at 5-cm intervals along the guide rod) was made at each transect. These 21 data points for each habitat variable were averaged prior to statistical analyses; thus, there is a single value for each sample.

Because this same approach was used for the investigations of distribution of six other native species inhabiting Aravaipa Creek (Barber and Minckley, 1966) and the upper Gila basin streams, it is possible to estimate habitat availability (from all transect data combined) in these streams. In contrast, data from the Verde River are only from specific locations where spikedace and red shiner were captured, and no estimate of habitat availability is possible.

Depth was measured with a modified meter rule, and velocity was measured 5 cm above the substrate. Initially, substrate was visually classified into one of five categories (sand, <2 mm; gravel, 3 to 16 mm; pebble, 17 to 64 mm; cobble, 65 to 256 mm; boulder, >256 mm). Because of frequent, near equal occurrence of two substrate types, gravel and pebble, at transects in Aravaipa Creek, two additional classes, sand-gravel and gravel-pebble, were added, for a total of seven substrate classes.

Depth and velocity data from transects with and without spikedace were compared using unpaired *t*-tests. Substrate class data were compared by Chi-square analyses. Habitat use among streams was subjected to analyses of variance (ANOVA) if homogeneity of variances (Bartlett's test) was established. If significant variation in samples was detected by ANOVA, Tukey's tests were used to determine and illustrate specific differences in habitat use among samples (Fig. 1).

RESULTS—In Aravaipa Creek, spikedace occupied significantly deeper and slower waters over smaller sized substrate (Table 1) than were generally available. By contrast, where spikedace were present in the Gila River at Cliff and the West and Middle Forks of the Gila, there were no significant differences ($P > 0.05$) between depth and velocity of water occupied by spikedace and those in which they were absent. Chi-square analyses, however, indicated substrate underlying waters used by spikedace was significantly smaller than that available in the Middle ($P < 0.001$) and West forks ($P = 0.03$) of the Gila River and than that used by spikedace in the lower Gila River (Table 1).

The variances in water depths among all streams in the upper Gila River and those where spikedace were present were homogenous (Bartlett's test, $P = 0.003$). ANOVA showed no significant ($P = 0.60$) differences in depths among streams where spikedace was present; however, velocities occupied by spikedace did vary significantly ($P = 0.004$) among the streams. Tukey's multiple range test grouped velocities of waters occupied by spikedace in the Middle and West forks of the Gila River ($\bar{X} = 14.2$ cm/s) apart from those occupied in the lower Gila and Aravaipa Creek ($\bar{X} = 30.1$ cm/s). Mean velocity of water occupied by spikedace in the Verde River was intermediate ($\bar{X} = 21.0$ cm/s).

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Available velocities did vary significantly ($P = 0.01$) in the upper Gila basin streams, New Mexico, but not ($P = 0.20$) in habitats occupied by spikedace. Considering all five streams sampled, there was no significant difference ($P > 0.05$) in overall physical habitat availability among the streams or that occupied by spikedace (Fig. 1).

Based on relative numbers of spikedace at transects rather than mere presence or absence of the species, spikedace preferred deeper, slower waters in Aravaipa Creek. That is, transects were selected with schools that contained spikedace (i.e., >10 fish, $n = 10$; >12 fish, $n = 7$), and habitat was compared with that of transects with a single fish ($n = 31$). Results showed mean depth of water occupied increased and mean velocity occupied decreased when schools of spikedace were present. Transects with 10 or more fish averaged 22.8 cm in depth, and those with 12 or more fish averaged 27.3 cm. Transects with a single fish averaged only 15.7 cm. By comparison, water velocity at these same transects averaged 25.7 cm/s and 22.7 cm/s compared with a mean of 36.6 cm/s at transects with a single spikedace. Using this same approach in the three upper Gila streams and the Verde, however, did not reveal any differences in either water depth or velocity between transects with a single spikedace versus those with more than one.

Adult spikedace predominated in samples from Aravaipa Creek. Although there was an obvious gradient in mean depth of water occupied from larvae (14.4 cm) through juvenile (17.1 cm) to adult (20.4 cm) fish, there was no significant difference ($P = 0.13$) in depth of water used among the three life stages (Rinne and Kroeger, 1988). Similarly, there was no significant difference ($P = 0.10$) in velocity of water occupied by the three life stages, but there was a tendency for larval and juvenile spikedace to occupy waters of slower velocity ($\bar{X} = 26.6$ versus 26.9 cm/s, respectively) than that of waters occupied by adults (35 cm/s). Finally, there was no significant difference in substrate underlying the waters occupied by the three life stages in Aravaipa Creek.

Because red shiners have been recorded in the Verde River and were noted in December 1989 sampling, this site was sampled in January 1990. Out of thirty-four transects sampled in the same reach (and riffles) of the Verde River sampled in 1989, 24 contained only red shiners, 9 contained only spikedace, and only 1 contained both species. Although spikedace were not captured in the 24 sites in 1990, they were captured in contiguous downstream reaches where they occupied near identical depths and velocities to those estimated in 1989 (Table 1). Substrate indexes also were near identical to those recorded in 1989.

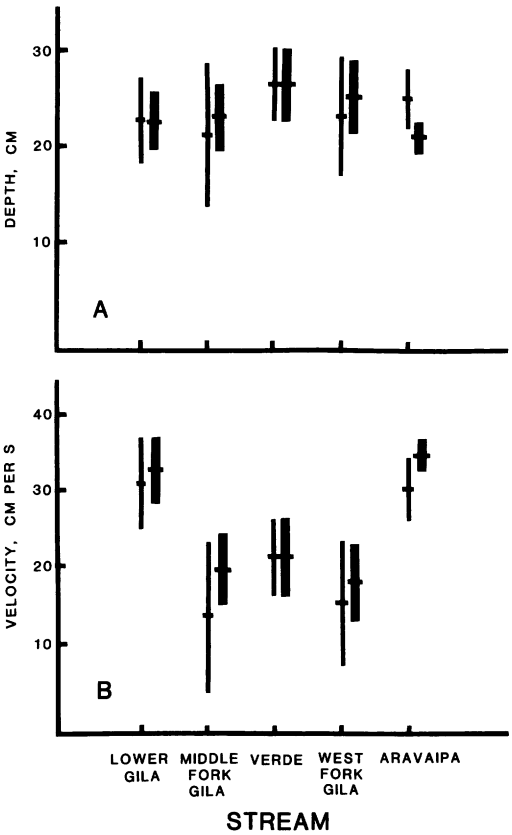

FIG. 1—Mean and 95% confidence limits of depth (A) and velocity (B) of waters occupied by spikedace, *Meda fulgida* (light line), compared with that available (heavy line) in several southwestern desert streams.

Red shiner occupied water depths very similar to spikedace but were found in significantly ($P < 1.1^{-7}$) slower water velocities (Table 1). All 24 sites that contained only red shiner had an organic-silt "false substrate" created by demersal aquatic macrophytes (e.g., *Chara, Potomegton*) trapping fine silt and sand. These same riffle sites were occupied by spikedace the previous winter but in absence of this type of substrate (Table 1). By comparison, all sites containing spikedace in 1990 were over open, variable-sized, mineral (gravel to cobble) substrate with the same composition (based on substrate indices) recorded in 1989. The reach containing spikedace commenced at the head of and continued throughout a higher gradient riffle. Eddying currents and shear zones abounded in this 30-m reach of stream.

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TABLE 1—Comparison of mean and median (in parentheses) depth and velocity of water and substrate composition occupied by spikedace (*Meda fulgida*), with habitat where absent in five streams, Arizona and New Mexico, and red shiner (*Notropis lutrensis*) in the Verde River. Significance (* = <0.05; ** = <0.01) between where spikedace are present (P) and absent (A) is indicated.

Stream	Occurrence	*n*	Mean (median) depth (cm)	Mean (median) velocity (cm/s)	Substrate index
Aravaipa Creek	P	40	24.9 ± 13 (23)**	29.8 ± 17 (28)*	2.9 (3)**
	A	144	19.9 ± 11 (17)**	35.7 ± 16 (36)*	3.4 (3)**
Gila River Cliff, New Mexico	P	19	22.7 ± 10 (24)	30.8 ± 9 (33)	4.6 (5)
	A	25	22.9 ± 9 (21)	34.0 ± 13 (38)	4.8 (5)
Middle Fork Gila River	P	7	21.1 ± 7 (18)	13.3 ± 14 (9)	2.0 (1)**
	A	27	23.3 ± 13 (20)	21.0 ± 17 (16)	3.5 (5)**
West Fork Gila River	P	10	23.1 ± 6 (24)	15.0 ± 8 (14)	2.8 (2)*
	A	19	26.1 ± 14 (23)	19.3 ± 14 (14)	4.4 (6)*
Verde River					
Spikedace (1989)	P	10	26.5 ± 6.7 (25)	21.0 ± 10 (20)	2.8 (2)
(1990)	P	10	25.2 ± 2.1 (25)	16.9 ± 1.5 (16)**	2.5 (2)
Red shiner	P	25	26.6 ± 1.8 (24)	6.2 ± 0.8 (5)**	

DISCUSSION—Until now, only a qualitative description of the habitat requirements of *Meda* has been available in the literature (Miller and Hubbs, 1960; Barber et al., 1970; Minckley, 1973). These researchers described the species as inhabiting "moving, deep" (0.6 to 1.3 m) waters and as typically found in "swift deep pools, or the deeper parts of long pools, near riffle mouths over sandy or gravelly bottoms." In the Gila River, adults were also observed by Miller and Hubbs (1960) on shallow, algae-dominated riffles. In the Verde River, they observed adult spikedace on a very swift riffle over a bedrock bottom; young occupied backwater areas over silt-sand bottom adjacent pools. Barber et al. (1970) noted that during the day, spawning females inhabited deeper pools and eddies. By comparison, males occupied riffles (8 to 15 cm) over sand gravel beds.

More recently, R. M. Anderson (in litt.) reported spikedace common only in moderate to swift riffles <30 cm deep and comprised of "gravel-rubble" (15 to 120 mm) substrate. D. L. Propst et al. (in litt.) reported that adult spikedace occupied waters with a mean depth of 19.3 cm, velocities of 49 cm/s over sand-gravel-cobble substrate. Although this average depth of water occupied by spikedace is comparable to my observations, the greater velocities reported by these workers might be attributable to their point of velocity measurement (i.e., 0.6 depth versus 5 cm off bottom). Their substrate description is too broad (i.e., spanning three substrate classes) to be compared to my categories.

Similar to Miller and Hubbs (1960), I recorded larval fish in "slow" currents in the immediate vicinity of riffles containing adults. Adult spikedace generally did not occupy areas with "slow" current or pools with no current. D. L. Propst et al. (in litt.) reported that water depths and velocities occupied by larval spikedace in the upper Gila basin were significantly less (8.4 cm and 8.4 cm/s, respectively) than those occupied by either juveniles (16.8 cm and 16.1 cm/s, respectively) or adults (19.3 cm and 49.1 cm/s, respectively). Similarly, adults and juveniles occupied significantly different habitat than larvae in Aravaipa Creek.

In general, my quantification of physical habitat for spikedace in streams in the three study areas confirmed the earlier, mostly qualitative descriptions of habitat use by spikedace. Despite slightly deeper waters being available on average in the upper Gila River streams and in the Verde River, similar water depths were occupied by spikedace in Aravaipa and these streams. However, my values are far below those (60 to 120 cm) reported by Miller and Hubbs (1960) but within the range of depths (20 to 30 cm, Table 1) listed by R. M. Anderson (in litt.) and D. L. Propst et al. (in litt.).

Overall, velocity and substrate occupied by spikedace paralleled availability of these two physical habitat factors in Aravaipa Creek and the upper Gila River study areas (Fig. 1, Table 1). Velocity in the Middle and West forks of the Gila River and in the Verde River was signifi-

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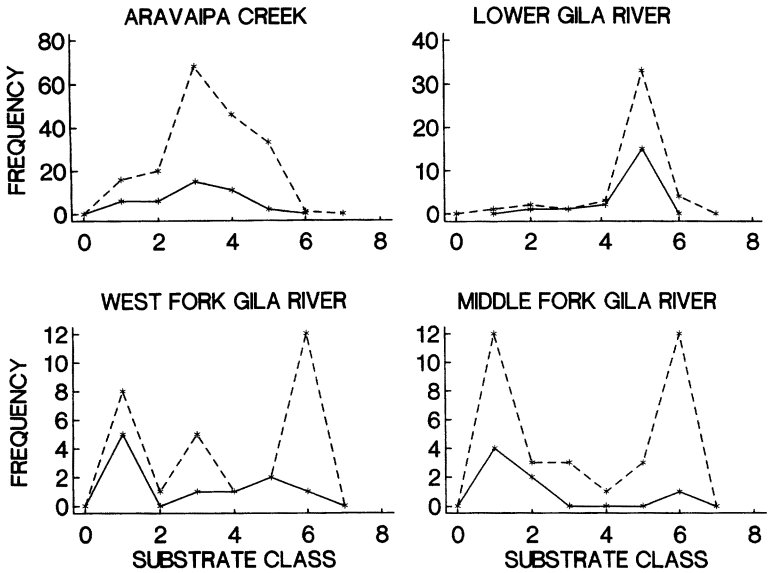

FIG. 2—Substrate availability (dashed line) compared to that used (solid line) by spikedace, *Meda fulgida,* in several southwestern desert streams.

cantly lower than mean velocity in Aravaipa and the lower Gila River site (Table 1). If one assumes that the number of individuals at respective transects is an indicator of optimum or preferred habitat, spikedace prefer deeper waters or pools with slow current. In Aravaipa Creek, such habitats were frequently associated with "shear zones" where two (or more) braids of streams converged. These areas and those along canyon walls or downstream of large boulders provided physical structure that produced eddying and sometimes pool formation. Based on observations, qualitative descriptions, and my (and others) collections, such habitats are frequented by spikedace. The water-column lifestyle of spikedace is facilitated by areas of reduced, eddying current and adequate water depth. Further, these areas are most often characterized by gravel-pebble substrate with lesser amounts of sand (Fig. 2). R. M. Anderson (in litt.) suggested spikedace occurred over slightly larger (gravel-rubble, 15 to 120 mm) substrate than I recorded in either Aravaipa or the three streams in the Upper Gila River.

In addition to alteration of aquatic habitats in the Southwest as described by Miller (1961), the introduction of the non-native red shiner has been suggested as contributing to the decline of spikedace (Minckley and Deacon, 1968). The red shiner is a "generalist" in habitat use (Cross and Collins, 1975; Matthews, 1985) and often becomes more abundant in degraded habitat generally considered adverse to, and having a negative impact on, more specialized, native midwestern fishes (Matthews and Maness, 1979). Conceivably, because of size and familial relationships alone, competition could occur between spikedace and red shiner for physical space in a stream co-inhabited by these two cyprinids.

Matthews and Hill (1979) studied the habitat of red shiner in both the field and laboratory and reported water temperature, speed (velocity), and depth as having the greatest impact on habitat selection by this species. Similar to spikedace, red shiners occupy consistently deeper (>20 cm) waters than available on the average in a stream. In the field, red shiners were most abundant in slower (0 to 7 cm/s) backwater and nonflowing pools over mixed substrate with little sand present. Recently, Matthews (1985), in a more comprehensive study of habitat across a large number of streams (100), found red shiner abundant in both "deep, swift" and "shallow, slow" waters over substrate with little sand. There is a consensus that the red shiner typically avoids clear waters and tolerates turbid waters (Cross, 1967; Cross and Collins, 1975; Pflieger, 1975; Smith, 1979; Matthews, 1985).

Based on physical habitat occupied by red shiner in midwestern streams, red shiner could compete with spikedace for space in a stream. Mean depth (20 to 30 cm) and associated substrate used by spikedace in Aravaipa and the upper Gila

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River (Table 1) is very similar to that (i.e., gravel-pebble) suggested by Matthews and Hill (1979) for red shiner. More specifically, in the Verde River red shiner occupied almost identical depths to spikedace in winter. By contrast, velocities listed in the literature for red shiner (0 to 7 cm/s) and those I measured in the Verde River were much less than means I estimated for spikedace (17 to 35 cm/s) in southwestern streams. Spikedace were present over a variety of substrate types, but occurred mostly over the larger substrate size classes (3 to 5; gravel-pebble; Fig. 2). This is in agreement with substrate selection reported for red shiner (Matthews and Hill, 1979; Matthews, 1985). In contrast, red shiners were collected over a silt-sand-vegetative substrate in the Verde River in winter 1990.

The tolerance of red shiner to turbidity, its high critical thermal maximum (Matthews and Maness, 1979), and the characteristic low faunal diversity of western streams (Minckley and Deacon, in press) may play an important role in the interactions or potential competition between these two cyprinid species. Matthews (1985) found red shiner more abundant in midwestern streams where fish species diversity was low. The typically low faunal diversity of native western fishes may give red shiner a competitive advantage over not only spikedace but also other native western fishes. Secondly, the tolerance by red shiner to turbidity, elevated water temperatures, and low dissolved oxygen content of water (Matthews and Hill, 1977) could be selective advantages for red shiner over spikedace during alteration of habitat caused by western land use practices (e.g., timber harvesting, mining, agriculture). On the other hand, the generally clear, shallow nature of many western streams may have a positive effect on spikedace and negative impact on this "generalist" which avoids clear waters. Adult red shiners occur in lower velocity (<7 cm/s) waters similar to those occupied by larval spikedace in the upper Gila basin (D. L. Propst et al., in litt.) and may impact spikedace in these habitats in early life stages.

Although comparison of habitats frequented by these two cyprinids suggests overlap may occur, preliminary observations where the two species co-occur in the Verde River indicate different patterns of habitat use based on velocity and substrate. Additional analyses of habitat use in other southwestern streams where the two species co-occur combined with carefully designed, controlled experiments to determine behavioral interactions among life stages are needed to define actual competition between the two. Abiotic disturbance has been suggested to be a key factor in determining the coexistence of the native Gila topminnow (*Poeciliopsis occidentalis*) and the introduced mosquitofish (*Gambusia affinis*) in the Southwest (Meffe, 1984). Both abiotic and biotic factors must be evaluated (Matthews, 1987) before conclusions on dispersion and competition between spikedace and red shiner can be made.

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